1.0 INTRODUCTION

The objective of this Sampling and Analysis Plan (SAP) is to identify the specific analytical needs, sampling requirements, data handling requirements and quality assurance/quality control (QA/QC) requirements for Consolidated Water Treatment Facility (CWTF) samples. This SAP outlines the sampling requirements for the following items:

- Influent Sources (e.g., OU1 groundwater, Environmental Restoration water);
- Process Monitoring (as determined to be necessary by the Responsible Project Manager);
- Treated Effluent (held in effluent storage tanks prior to discharge); and
- Waste Streams (neutralized ion exchange regenerant, spent bag filters, filter press sludge, etc.)

The objectives for sampling during system operation are to ensure the treatment system's ability to meet treatment goals and to confirm that treated effluent meets requirements for discharge. It is also used to evaluate ion exchange resin performance and to determine proper disposal of process waste and spent media.

2.0 OVERVIEW

The CWTF is located in trailers T-900A and T-900B and Building 891. The facility accepts water from four primary influent sources and treats these waters through four treatment processes.

The CWTF currently treats potentially contaminated water from the following sources:

- OU-1 groundwater (French Drain, Collection Well and Building 881 Footing Drain);
- Decontamination water from the Main Decontamination Facility (MDF);
- Decontamination water from the Protected Area Decontamination Facility (PADF); and
- Other Environmental Restoration (ER) waters.

Trailers T-900A and T-900B and Building 891 contain the following treatment processes:

- A chemical precipitation system, including
  - a cross-flow membrane microfiltration system;
  - a solids dewatering system; and
  - a treated effluent pH adjustment/transfer system;
- An ultraviolet/hydrogen peroxide (UV/H_2O_2) oxidation system;
- A liquid-phase granular activated carbon (GAC) unit; and
- A 4-column ion exchange (IX) system with
  - an associated acid/caustic regeneration system;
  - a degasifier; and
  - a spent regenerant neutralization system.

Water to be treated at the CWTF is temporarily stored in influent tanks T-201 or T-202 (15,000 gallons each) or in T-200 (10,000 gallons). A skid-mounted oil-absorbent media drum is available for the pretreatment of oily waste waters prior to off-loading tanker truck contents into a CWTF influent tank. When an influent tank is full, the contents are pumped either to T-900A/T-900B or to Building 891 for treatment.

If chemical precipitation is the first unit operation, water will be pumped from one of the influent tanks (T-200, T-201 or T-202) into reaction tank No. 1 where the pH is lowered to approximately 4.5 with sulfuric acid to break carbonate complexation of uranium. Ferric sulfate is also added as a coagulant and co-precipitation agent. Water overflows from reaction tank No. 1 to reaction tank No. 2 where lime and sodium hydroxide are added to raise the pH to approximately 10.5. The high pH causes the precipitation of iron and dissolved heavy metals as metal hydroxides. Radionuclides and metals adsorb to the hydroxide particulates that form. The high pH water in reaction tank No. 2 then gravity flows to concentration tank TK-8 located in T-900A and is subsequently pumped to the microfiltration system. The filtrate is collected and directed to pH adjustment/transfer tank TK-11. Sulfuric acid is used to adjust the membrane filtrate collected in pH adjustment/transfer tank TK-11 to a pH between 6.0 and 9.0. After pH adjustment, the water is pumped to influent tanks T-200 or T-201 for recirculation through the T900A/T900B system or to influent tanks T-201 or T-202 for routing to the UV/H_2O_2 Oxidation System and eventual storage in effluent storage tanks T-205, T-206 or T-207.

Solids in Concentration tank TK-8 are periodically pumped to sludge holding tank TK-12 where a solids dewatering system is used to process the solids. This system includes an air-operated slurry

pump to transfer concentrated solids from sludge holding tank TK-12 to the filter press. The filter press removes water from the solids and creates a filter cake that contains 35 to 50% solids by weight. The filtrate produced by the filter press is recycled to concentration tank TK-8. The filter cake is transferred into drums placed beneath the elevated filter press. The filter cake sludge is packaged in accordance with 4-D99-WO-1100, *Solid Radioactive Waste Packaging*.

Water is pumped from influent tanks T-201 or T-202 to the UV/H_2O_2 Oxidation System. The UV/H_2O_2 process oxidizes the organic constituents using 50 percent H_2O_2 - a strong oxidizer - and UV light. The UV light serves to catalyze the oxidation by converting the peroxide to hydroxyl radicals, thus making it a more effective oxidant. Effluent from the UV/H_2O_2 process flows to either the GAC unit or to surge tank T-203.

Water treated in the GAC unit passes through 3000 pounds of granular activated carbon. During treatment, organic contaminants collect and adhere to the porous carbon surface. Water exiting the GAC system is routed to surge tank T-203.

Water in surge tank T-203 is pumped in series to the first two ion exchange columns (IX column Nos. 1 and 2). The first column, IX column No. 1, is provided for removing uranium in the carbonate complex. IX column No. 1 contains a strong base anion resin in the chloride form (AMBERLITE IRA-900). IX column No. 2 has a weak acid cation resin in hydrogen form (IONAC CC) that removes positively charged cations associated with alkalinity in water. The water flows from IX column No. 2 to a degasifier where liberated carbon dioxide escapes to the atmosphere. From the degasifier (sump T-100), the water is pumped to the final two ion exchange columns (IX column Nos. 3 and 4) in series. IX column No. 3 contains a strong acid cation resin (IONAC C-267) that removes remaining positively charged cations including excess hardness and metals. IX column No. 4, with weak base anion resin (IONAC AFP-329), is the last unit and removes excess negatively charged anions. The treated water then exits the building and flows to one of the effluent storage tanks (T-205, T-206 or T-207).

Treated effluent is stored in effluent storage tanks T-205, T-206 and T-207 (159,000 gallons each) and is sampled when an effluent tank is filled to maximum working volume. Analytical test results are compared to the CWTF Chemical Specific ARAR/Effluent Wastewater Treatment Standards (Appendix 1) and treated effluent is acceptable for discharge to the South Interceptor Ditch (SID) when these standards are met. Effluent that does not meet these standards is recirculated back through the appropriate unit process for additional treatment in accordance RMRS/OPS-PRO.152, *CWTF Treated Effluent Recirculation*.

This document supercedes Consolidated Water Treatment Facility Sampling and Analysis Plan, Revision 0.

3.0 DATA QUALITY OBJECTIVES

Based on EPA QA/G-4, Guidance for Using the Data Quality Objective Process, the data quality objectives (DQOs) are designed to ensure that the type, quantity and quality of data used in decision making are appropriate for the intended application. The following sections discuss the CWTF DQOs and parameters that will be used to ensure data quality and useability.

3.1 DATA QUALITY OBJECTIVES

Routine Influent Sources

The OU1 groundwater sources (e.g., French Drain Sump [891COLGAL], Collection Well [891COLWEL] and Building 881 Footing Drain [SW13494]) are well characterized, therefore, the purpose of the quarterly sampling at these locations is to track the contamination trends from these sources. Please note that this procedure will generally reference OU1 groundwater sources by sampling location code, not sampling location name.

Historically, sampling at the OU1 groundwater locations was defined in the OU1 Interim Measure/Interim Remedial Actions (IM/IRA) Plan. Samples collected will follow the procedure outline in *Containing, Preserving, Handling, and Shipping Soil and Water Samples,* RMRS/OPS-PRO.069. The OU1 locations are already well characterized and in an effort to standardize sampling activities, the sampling at these locations will be streamlined as follows:

- VOAs;
- Dissolved metals; and
- Dissolved isotopic Uranium.

For each major analytical group, the standard list of analytes at the required detection limits will be analyzed. Required detection limits for each analyte can be found in the Rocky Flats Statement of Work for Analytical Measures. Analytical methods are listed in Table 4-1.

No sampling of routine groundwater purge water or water from the Main Decontamination Facility and Protected Area Decontamination Facility will be done prior to acceptance and treatment at the CWTF because historic information indicates that this water has little contaminant variation. However, the Responsible Manager may choose to increase sampling for any of these influent waters based on circumstances/process knowledge.

Non-Routine Influents (such as waters from ER Projects)

The Responsible Manager will determine the sampling needs for non-routine influents based on process knowledge and engineering experience. In general, this sampling may include VOCs, SVOCs, PCBs, metals, radionuclides, TOC, cyanide, sulfide, pH, NO_2/NO_3 and water quality. Sampling influent waters will determine treatment options and discharge sampling requirements.

Process Samples

All process sampling is at the discretion of the Responsible Manager to determine process efficiencies.

Effluent Tank Sampling

The treated effluent is sampled and results are compared to the CWTF Chemical Specific ARAR/Effluent Wastewater Treatment Standards in Appendix 1 to determine if the effluent is acceptable for discharge to the SID in accordance with RMRS/OPS-PRO.144, *CWTF Treated Effluent Discharge*. The CWTF Action Levels are based on the *Surface Water Action Levels and Standards*, RFCA Attachment 5, July 1996 and Draft Modifications to RFCA Attachment 5, March 1999.

For each major analytical group, the standard list of analytes at the required detection limits (ultra low required detection limits for metals) will be analyzed. Required detection limits for each analyte can be found in the Rocky Flats Statement of Work for Analytical Measures. Analytical methods are listed in Table 4-1.

At a minimum, the Effluent Storage tanks will be sampled for the following:

- VOCs;
- Total metals;
- Total radionuclides (Americium 241, Plutonium 239/240, Strontium 90, Tritium, Uranium[1], Gross Alpha, Gross Beta);
- Nitrate (as N) + Nitrite (as N); and
- pH.

The Responsible Manager may determine, based on knowledge of the treatment plant influent and engineering judgment, that additional analyses are necessary. These might include:

- SVOCs and PCBs; and
- Additional water quality (e.g., chromium VI, cyanide, sulfide (as H_2S), fluoride).

It is not anticipated that it will be necessary to sample for pesticides and herbicides, however, the Responsible Manager may determine that these analyses are necessary based on knowledge of the influent waters.

Waste Stream Sampling

The appropriate sampling of each individual waste stream for waste disposition will be determined by the Responsible Manager based on knowledge of the waters processed and expected disposition. Sampling is conducted to determine whether the chemical and physical properties of the waste comply with on-site and/or off-site waste disposal criteria.

For each major analytical group, the standard list of analytes at the required detection limits (ultra low required detection limits for metals) will be analyzed. Required detection limits for each analyte can be found in the Rocky Flats Statement of Work for Analytical Measures. Analytical methods are listed in Table 4-5.

[1] Uranium (total) which is reported in mg/L will be converted to pCi/L using the conversion for natural uranium of 677 pCi/L.

Solids will be sent to a Utah Certified Lab in accordance with the Customer Information Manual. Analytical results will be compared to the Land Disposal Requirements (LDR) and the Waste Acceptance Criteria, as applicable, to determine on-site or off-site disposal. If results do not comply with LDR standards, the waste will be disposed of off-site when the Waste Acceptance Criteria have been met.

3.2 PARCC PARAMETERS

The Precision, Accuracy, Representativeness, Completeness, and Comparability parameters (PARCC parameters) can be used as a means of ensuring and assessing the quality and useability of laboratory data as described RF/RMRS-98-200, *Evaluation of Data for Useability in Final Reports*. The analytical program specifies using EPA-approved methods and analytical methods referenced in the Rocky Flats Statement of Work for Analytical Measurements since these methods and associated QA/QC protocols are generally considered industry standards for producing accurate and precise data.

Accuracy is a qualitative measurement that refers to the degree of difference between calculated or measured values and the true value of a parameter. The closer the measurement to the true value, the more accurate the measurement. Precision is a qualitative measurement that refers to the reproducibility or degree of agreement among replicate measures of a parameter. The closer the numerical values of the measurements are to each other, the lower the Relative Percent Difference (RPD).

Field duplicate samples and sampling equipment rinseate blanks (in accordance with Section 4.5 of this document) will be taken to ensure sample quality. A comparison between real and duplicate samples must meet a Duplicate Error Ratio (DER) of 1.96 or less for radiological samples, a 30% or less RPD for water samples and a 40% or less RPD for solid samples. The DER and RPD equations can be found in RF/RMRS-98-200, *Evaluation of Data for Usability in Final Reports*. Effluent samples will be validated at 100% and all other samples will be validated at 25%.

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point or an environmental condition. Representativeness is a qualitative parameter that emphasizes the proper design of the sampling program.

A completeness goal of 90% is expected for the CWTF data; that is, for each sample taken and each analysis performed during the CWTF sampling activities, the usable data points will be at least 90% of the theoretical amount of data points. Completeness will be determined in accordance with *Evaluation of Data for Useability in Final Reports*, RF/RMRS-98/200.

Comparability is a qualitative parameter that expresses the confidence with which one data set can be compared with another. To achieve comparability, CWTF sampling will follow the approved SAP, which includes the use of standardized analytical protocols, data collection following RMRS/OPS-PRO.069, *Containing, Preserving, Handling and Shipping Soil and Water Samples* and will report data in consistent units of measurement.

4.0 SAMPLING STRATEGY AND REQUIREMENTS

This section addresses sample locations, frequency, specific analytical needs, sampling requirements and QA/QC requirements.

4.1 SAMPLING LOCATIONS AND FREQUENCY

Provisions are made for sample collection at specific points in the collection and treatment system to evaluate influent and effluent characteristics, unit process effectiveness and waste stream characteristics.

891COLGAL, 891COLWEL and SW13494 will be sampled at their respective sample ports. The sampling frequency for OU1 waters is quarterly.

Routinely accepted waters that will not be sampled unless determined to be necessary by the Responsible Manager include Main Decontamination Facility decontamination waters, Protected Area Decontamination Facility decontamination waters and groundwater purge water.

Prior to CWTF acceptance of ER Project water, samples will be collected and analyzed with the results submitted to the Responsible Manager for assessment in accordance with RMRS/OPS-PRO.149, *CWTF Influent Collection, Transfer, and Storage Operations*. The Responsible Manager may request additional samples/analyses not incorporated into this SAP based on knowledge of the influent source/process and may also waive process analysis if knowledge of the influent water is adequate

Sampling will take place at the aqueous hand sample ports located on each treatment unit. The treated effluent will be sampled from the effluent holding tanks. Sampling frequency for process samples is at the discretion of the Responsible Manager. Samples of neutralized resin regenerant will also be collected at the discretion of the Responsible Manager before transferring the contents of the neutralization tank to Building 374 for disposal. The effluent tanks will be sampled when they are filled, prior to discharge to the SID.

Sampling locations and sampling frequency are summarized in Table 4-1 through Table 4-5. A description of the sampling procedures is contained in Section 5.0.

TABLE 4-1
Sampling Summary of Influent Waters

SWD Location Code	Sample Location	Sample Type	Sampling Frequency[1]	Analytical Suites	Analytical Methods/Protocol Used
891COLWEL	Collection Well	Aqueous	One grab sample per quarter	VOAs; Dissolved metals; Dissolved Isotopic Uranium	VOAs 524.2; Dissolved metals EPA CLP.SOW; Dissolved U isotopes Alpha spectrometry
891COLGAL	Collection Gallery - French Drain Sump	Aqueous	One grab sample per quarter	VOAs; Dissolved metals; Dissolved Isotopic Uranium	VOAs 524.2; Dissolved metals EPA CLP.SOW; Dissolved U isotopes Alpha spectrometry
SW13494	881 Footing Drain	Aqueous	One grab sample per quarter	VOAs; Dissolved metals; Dissolved Isotopic Uranium	VOAs 524.2; Dissolved metals EPA CLP.SOW; Dissolved U isotopes Alpha spectrometry
N/A	MDF	N/A	No samples required	N/A[2]	N/A
N/A	PADF	N/A	No samples required	N/A[2]	N/A
N/A	Purge water	N/A	No samples required	N/A[2]	N/A
Project Specific	ER Project Water	Aqueous	Adequate to characterize influent	Analytical suites are at the discretion of the Responsible Manager based on the influent source and treatment unit process data needs. In general, this sampling will include VOCs, SVOCs, PCBs, metals, radionuclides, TOC, cyanide, sulfide, pH, NO_2 /NO_3 and water quality[3].	

[1] Sampling frequency and analytical parameters may be increased at any time at the request of the Responsible Manager.

[2] Several years of historic sample results indicate that the CWTF can accept and treat this water.

[3] Water Quality includes TDS, F, SO_4, Cl, and pH.

N/A = Not applicable

TABLE 4-2
Sampling Summary of Process Waters

SWD Location Code	Sample Location	Sample Type	Sampling Frequency[1]	Analytical Suites	Analytical Methods/Protocol Used
891CAINF	Influent to Clay Absorbent	Aqueous	Grab samples as requested	Optional	Analytical Suite Dependent
891CAEFF	Effluent from Clay Absorbent	Aqueous	Grab samples as requested	Optional	VOCs and SVOCs EPA Level II
RS2	Precipitation System Influent V-936	Aqueous	Grab samples as requested	Optional	Analytical Suite Dependent
RS5	Microfiltration System Effluent V-945	Aqueous	Grab samples as requested	Optional: Metals and/or Radionuclides[2]	VOC, Metals non-CLP, Radiochemistry
891UVINF	Influent to UV/H_2O_2 Oxidation System from influent tanks T-200 ,T-201, or T-202 V-78	Aqueous	Grab samples as requested	Optional	Optional: VOCs EPA Level II, VOCs EPA 8260, Total Metals TCL[3] or Level II, Radiochemistry, pH, NO_2/NO_3, and water quality[4] by EPA Methods
891UVEFF	UV/H_2O_2 Oxidation System Effluent, V-14	Aqueous	Grab samples as requested	Optional: VOCs	VOCs EPA 8260
891GACEFF	GAC System Effluent, V-175	Aqueous	Grab samples as requested	Optional: VOCs	Optional: VOCs EPA Level II, VOCs EPA 8260
891IX1INF	IX Column No. 1 Influent T-203, V-36	Aqueous	Grab sample as needed	Optional: Radionuclides	Total Uranium
891IX1EFF	IX Column No. 1 Effluent V-40	Aqueous	Grab samples as requested	Optional: Radionuclides	Total Uranium
891IX2EFF	IX Column No. 2 Effluent V-39	Aqueous	Grab samples as requested	Optional: Metals	Optional: Total Metals non-CLP
891IX3EFF	IX Column No. 3 Effluent V-41	Aqueous	Grab samples As requested	Optional: Metals, NO_2/NO_3	Optional: Total Metals non-CLP, NO_2/NO_3 by EPA Methods
891IX4EFF	IX Column No. 4 Effluent V-96	Aqueous	Grab samples As requested	Optional: NO_2/NO_3	Optional: NO_2/NO_3, Fluoride by EPA Methods

[1] Sampling frequency and analytical parameters may be increased at any time at the request of the Responsible Manager.

[2] Radionuclides may include gross alpha and beta activities, Pu 239/240, Am 241, U 233/234, U 235 and U 238.

[3] Target Compound List (TCL) by CLP or SW-846 Methods.

[4] Water Quality includes TDS, F, SO_4, Cl and pH.

TABLE 4-3
Sampling Summary of Effluent Water

SWD Location Code	Sample Location	Sample Type	Sampling Frequency[1]	Analytical Suites[2]	Analytical Methods/Protocol Used
891T-205 891T-206 891T-207	Effluent Tank Discharge T-205, V-96 T-206, V-96 T-207, V-96	Aqueous	One grab sample per tank before discharge	VOCs, Total metals, Total radionuclides[3], pH, NO_2/NO_3, water quality, Sr and Tr	VOCs EPA 8260, Metals TCL[4], Radiochemistry, pH, and NO_2/NO_3

TABLE 4-4
Sampling Summary of Virgin Media

SWD Location Code	Sample Location	Sample Type	Sampling Frequency[1]	Analytical Suites	Analytical Methods/Protocol Used
891VCA	Virgin Clay Absorbent	Solid	Grab samples as requested	Radionuclides[5]	Radiochemistry
891VGACL	Virgin GAC (Liquid-Phase) 891 GAC Unit	Solid	Grab samples as requested	Radionuclides[5]	Radiochemistry
891VGACV	Virgin GAC (Vapor-Phase) Influent tank T-200, Drum-1	Solid	Grab samples as requested	Radionuclides[5]	Radiochemistry
891VGACV	Virgin GAC (Vapor-Phase) T-900A, Drum-2	Solid	Grab samples as requested	Radionuclides[5]	Radiochemistry
891VGACV	Virgin GAC (Vapor-Phase) T-900B, Drum-3	Solid	Grab samples as requested	Radionuclides[5]	Radiochemistry
891VBAGFIL	Virgin Bag Filter 891 Sump	Solid	Composite samples as requested	Radionuclides[5]	Radiochemistry
891VESIX1[6] 891VESIX2[6] 891VESIX3[6] 891VESIX4[6]	Virgin Ion Exchange Resin: IX#1 IX#2 IX#3 IX#4	Solid	Grab samples as requested	Optional	Analytical Suite Dependent

[1] Sampling frequency and analytical parameters may be increased at any time at the request of the Responsible Manager.

[2] Cyanide, Sulfide, SVOCs, and PCBs will be analyzed as required by influent characterization.

[3] Radionuclides may include gross alpha and beta activities, Pu 239/240, Am 241, U 233/234, U 235 and U 238.

[4] Target Compound List (TCL) by CLP or SW-846 Methods.

[5] Radionuclides include gross alpha and beta activities, Pu 239/240, Am 241, Sr 90, Tritium and total Uranium.

[6] Sampling parameters must certify compliance with LDR requirements.

TABLE 4-5
Sampling Summary of Process Waste and Spent Media

SWD Location Code	Sample Location	Sample Type	Sampling Frequency[1]	Analytical Suites	Analytical Methods/Protocol Used
891SCA[2]	Spent Clay Absorbent	Solid	Grab samples as requested	Metals[3], SVOCs[3], VOCs[3], Radionuclides[4]	EPA 1311 TCLP: VOCs Method 8260, SVOCs Method 8270, Metals 6010 and 7000s Methods. Radiochemistry. Optional: PCBs
RS8[2]	Filter Press Cake	Solid[5]	Grab samples as requested	Metals[3], SVOCs[3], VOCs[3] Radionuclides[4]	EPA 1311 TCLP: VOCs Method 8260, SVOCs Method 8270, Metals 6010 and 7000s Methods. Radiochemistry. Optional: PCBs
891SBAGFIL	Spent Bag Filter 891 Sump	Solid	Composite samples as requested	Radionuclides[4]	Radiochemistry
RS10 RS11	Spent Cleaning Tank Solution Spent Flush Tank Solution	Aqueous	Grab samples as requested	Optional: Metals, pH, Radionuclides[4]	Metals TCL[6], pH Level II, Radiochemistry
RS9[2]	Spent GAC (Liquid-Phase) 891 GAC Unit	Solid	Grab samples as requested[7]	Metals[3], SVOCs[3], VOCs[3] Radionuclides[4]	EPA 1311 TCLP: VOCs Method 8260, SVOCs Method 8270, Metals 6010 and 7000s Methods. Radiochemistry. Optional: PCBs
891REGTANK	IX Reg. Neutralization Tank T-210, HVC-210	Aqueous	Grab samples as requested prior to transfer to Building 374	Radionuclides[3], pH	Gross Alpha/Beta Level II (Rad Screen), pH Level II, Optional every 30 transfers: VOCs EPA 8260, Total Metals TCL[5], Radionuclides
891SGACV[6] 891SGACV[6] 891SGACV[6]	Spent GAC (Vapor-Phase) influent tank T-200, Drum-1 T-900A, Drum-2 T-900B, Drum-3	Solid	Grab samples as requested	VOCs[3], Radionuclides[4]	Total VOCs EPA Method 8260, Radionuclides[4]
891SESIX1[2] 891SESIX2[2] 891SESIX3[2] 891SESIX4[2]	Spent Ion Exchange Resin: IX#1 IX#2 IX#3 IX#4	Solid	Grab samples as requested	VOCs[3], Radionuclides[4]	Total VOCs EPA Method 8260, Radionuclides[4]

[1] Sampling frequency and analytical parameters may be increased at any time at the request of the Responsible Manager.

[2] Sampling parameters must certify compliance with LDR requirements.

[3] Analyte list for LDR compliance based on TCLP Metals, SVOCs and VOCs.

[4] Radionuclides may include gross alpha and beta activities, Pu 239/240, Am 241, U 233/234, U 235 and U 238.

[5] One grab sample (per drum, taken from plate 8) for VOCs and SVOCs and one composite sample (composited from all drums, taken from plates 4, 8 and 12) for metals and radionuclides.

[6] Target Compound List (TCL) by CLP or SW-846 Methods.

[7] *Samples from top 6" of unit bed after removing from service.*

4.3 ANALYTICAL METHODS

Tables 4-1 through 4-5 also summarize the analytical suites and analytical methods for the anticipated contaminants of concern. EPA's contract laboratory program (CLP) protocols are considered Level IV analytical methods. The CLP protocols are based on the EPA SW846 methods for analyzing wastewaters and solid wastes. The analytical methods are also described in Standard Methods for the Examination of Water and Wastewater and Methods for Chemical Analysis of Water and Wastes. The methods proposed for sample analysis are those recommended by the EPA and are deemed consistent with the data quality objectives. In addition, the Rocky Flats Statement of Work for Analytical Measurements will be used.

The analytical accuracy and precision goals are presented in the respective methods. These criteria include surrogate recoveries, matrix spike recoveries, matrix spike duplicate or laboratory duplicate precision, calibration linearity, laboratory control sample analyses, etc. Refer to the CLP protocols, the analytical methods and the Rocky Flats Statement of Work for Analytical Measurements for an exact description of the QA/QC measures and acceptance ranges for each method.

4.4 BOTTLE AND PRESERVATION REQUIREMENTS

Tables 4-6 and 4-7 show the bottle and preservation requirements, storage temperature requirements and maximum holding time for the aqueous and solid samples listed in Tables 4-1 through 4-5. Modifications to bottle size, type and preservation are allowed if approved by Analytical Services Division (ASD).

TABLE 4-6

Bottle and Preservation Requirements for Water Analysis

Analysis[1]	Bottle[2]	Preservative[3,4]	Maximum Holding Time
Radiological Screen	40mL	none	-
VOC	3 X 40ml amb./glass	4°C/HCl[5]	14 days
SVOC	Liter amb./glass	4°C	7 day extract/40 day analysis
Pest/PCB	Liter amb./glass	4°C	7 day extract/40 day analysis
Metals	Liter/poly	4°C/HNO_3	6 months[6]
TOC	60mL/poly	4°C/H_2SO_4	28 days
Sulfide	500mL/poly	4°C/ZnOAc and NaOH	7 days
Water Quality/pH	Liter/poly	4°C	7-28 days
Cyanide	Liter/poly	4°C/NaOH	14 days
NO_2+NO_3	500ml/poly	4°C/H_2SO_4	28 days
A/B	Liter/poly	HNO_3	6 months
Pu, Am, U[7]	4 Liter/poly	HNO_3	6 months
Tritium	100 or 125ml/glass	none	6 months
Strontium	Liter/poly	none	6 months

[1] Due to time constraints during sampling, the samples will be placed in a cooler with blue ice (if required) and transferred to the laboratory or sample refrigerator as soon as possible to chill the samples to 4°C (2°C to 6°C). The field temperature of the cooler/samples will not be monitored to prevent causing a rise in temperature in the cooler/samples by opening the cooler multiple times. Radiological samples do not require refrigeration but must be secured in a cool, dry area to minimize the chance of cross-contamination.

[2] Sample bottles may be bagged in the field, in the subcontractor trailer, or delivered to the on-site or local laboratory without bags. The sampler/packer shall use best judgment when packing samples and delivery of samples to the on-site or local lab will not require the stringent packing requirements applicable to off-site shipments. Multiple analytes may be combined in bottles if volumes and preservation are alike.

[3] All non-volatile samples preserved with acid must be checked for pH; they must be below pH 2 for proper preservation.

[4] Samples preserved with NaOH must be above pH 12 for proper preservation.
Sulfide must have a pH greater than 9 for proper preservation.

[5] As directed by CDPHE, groundwater samples will discontinue use of VOC preservation with HCl.

[6] TCLP Mercury maximum holding time is 28 days for extraction and 28 days for analysis.

[7] Groundwater personnel will collect a 1L poly sample for dissolved Uranium at 891COLWEL, 891COLGAL and SW13494. Sample preservation and maximum holding time will follow Pu/Am/U requirements.

TABLE 4-7

Bottle and Preservation Requirements for Solid Analysis

Analysis[1]	Bottle[2]	Preservative[3]	Maximum Holding Time
Radiological Screen	40ml to 8oz/glass or poly	none	-
Total Volatiles	4 to 8oz/glass	4°C	14 days
TCLP Volatiles	8oz/glass	4°C	14 days extract/14days analysis
TCLP Semivolatiles prep/40days analysis	8oz/glass	4C°	14 days extract/7 days
Total PCBs	8oz/glass	4C°	14 days extract/40days analysis
Radiochemistry	8oz to 1L/glass or poly	none	6 months
Reactivity(CN^-,H_2S) pH, EOX	8oz/glass	4°C	7-14 days
TCLP Metals	8oz/glass	4°C	6-mo extract/6-mo analysis[4]
Proctor Test/ Gradation	5gal/plastic	none	Not specified
Moisture Content	2qt/poly bag or equiv.	none	Not specified
Pre-shipment Analysis[5]	1L/glass	none	Not specified

[1] Due to time constraints during sampling, the samples will be placed in a cooler with blue ice (if required) and transferred to the laboratory or sample refrigerator as soon as possible to chill the samples to $4^oC \pm 2^oC$. The field temperature of the cooler/samples will not be monitored to prevent causing a rise in temperature in the cooler/samples by opening the cooler multiple times. Radiological samples do not require refrigeration but must be secured in a cool, dry area to minimize the chance of cross-contamination.

[2] Sample bottles may be bagged in the field, in the subcontractor trailer, or delivered to the on-site laboratory without bags. The sampler/packer shall use best judgment when packing samples and delivery of samples to the on-site lab will not require the stringent packing requirements applicable to off-site shipments. Multiple analytes may be combined in bottles if volumes and preservation are alike.

[3] Glass containers require Teflon-lined lids. Multiple analytes may be taken in larger single jars.

[4] TCLP Mercury maximum holding time is 28 days for extraction and 28 days for analysis.

[5] Customer Information Manual, ENVIROCARE of Utah, 1997.

4.5 FIELD QUALITY CONTROL

Field QC samples will be collected to ensure the accuracy and precision of the sampling procedures. Field sampling quality control will consist of the following:

- Collection of field duplicate samples will be at a minimum of one per twenty discharge or influent samples;
- Collection of sampling equipment rinsate blanks at a minimum of one per twenty discharge or influent samples (as appropriate); and
- Collection of a trip blank (volatile organic compounds only) at a minimum of one per discharge.

5.0 SAMPLING PROCEDURES

This section discusses the methods for collecting, managing, screening, packaging and shipping CWTF samples.

5.1 SAMPLE COLLECTION

Samples will be collected in accordance with *Containing, Preserving, Handling, and Shipping Soil and Water Samples*, RMRS/OPS-PRO.069 and *Surface Water Sampling*, RMRS/OPS-PRO.081, as well as procedures set forth in this SAP. CWTF personnel will collect CWTF samples and groundwater personnel will collect OU1 samples.

5.1.1 OU1 SAMPLE COLLECTION

SW13494 will be sampled in accordance with *Surface Water Sampling*, RMRS/OPS-PRO.081. Samples will be collected from the footing drain using the dip sample collection method.

Sample ports are used to collect samples from 891COLWEL and 891COLGAL. 891COLWEL has tubing that is removed after each sampling and 891COLGAL has tubing

that remains attached to the sample port at all times. The sample ports must be purged for three minutes before sampling.

The field data collected from 891COLWEL, 891COLGAL and SW13494 will include pH, conductivity, temperature and turbidity. These parameters will be collected on 891COLWEL and 891COLGAL at the tail end of their respective purges. SW13494 field parameters will be collected concurrently with laboratory samples.

5.1.2 CWTF SAMPLING COLLECTION

When collecting CWTF process water samples, it is important that the particular unit process being sampled has been in operation for an appropriate period of time to ensure that the water contents of the unit have been purged. This will ensure that the sample is representative of the process conditions at the time of sampling. The UV/H_2O_2, GAC and IX systems should be in operation for at least two hours before sampling. The Precipitation/Microfiltration system should be in operation at least 30 minutes before sampling.

In addition to ensuring that a particular unit process has been purged prior to sampling, it is also important to ensure that the sample port is purged prior to sample collection. The purge time for the UV, GAC, Precipitation/Microfiltration and IX sample ports is 30 seconds. The purge time for the effluent storage tanks is three minutes.

CWTF samples will be collected in accordance with RMRS/OPS-PRO.069, *Containing, Preserving, Handling, and Shipping Soil and Water Samples*. The CWTF aqueous hand sample ports are equipped with attached tubing. The T-210 regenerant is neutralized according to RMRS/OPS-PRO.156, *CWTF Ion Exchange System Neutralization and Transfer Operations* and is sampled when the tank is full. Filter press cake is sampled as it is removed from the filter press and placed in drums in accordance with 4-I61-ENV-OPS-FO.43, *Filter Press Operation and Cleaning - CWTF*. Liquid and vapor phase GAC and IX resin will be sampled when it is determined that the GAC or resin is spent. Effluent is sampled prior to discharge when an effluent storage tank is filled to maximum working volume.

The field data collected on the CWTF influent and discharge samples will include pH, conductivity and temperature. Temperature will be monitored using a thermometer or temperature recording instrument that has been calibrated against a National Institute of Standards and Testing (NIST) traceable standard thermometer. It is not necessary to follow a particular bottle order when collecting the samples.

Purge water drained from the treatment system during sampling should be returned to the treatment system. Plastic sheeting used during sampling should be disposed of as specified in the Building 891 WSRIC. Spills will be collected and handled in accordance with the Hazardous Waste Requirements Manual, 1-10000-HWR. Personal protective equipment will be removed and handled as outlined in 5-21000-OPS-FO.06, *Handling of Personal Protective Equipment* and Section 5.4 of this document. All procedures shall be in accordance with the CWTF Health and Safety Plan, RF/ER-96-0118.

5.2 SAMPLE CUSTODY

The chain of custody (COC) form for sampling shall be filled out in accordance with RMRS/OPS-PRO.069, *Containing, Preserving, Handling, and Shipping Soil and Water Samples* and 4-B29-ER-OPS-FO.14, *Field Data Management*. The sampling team will be responsible for initiating the COC and must sign and date the form when relinquishing samples for shipment or analysis. Custody seals shall be placed on the sample containers after the samples are collected and prior to being relinquished from the sampler.

5.3 SAMPLE EQUIPMENT DECONTAMINATION

Equipment used at more than one location for collection of CWTF samples shall be decontaminated between sampling locations. Decontamination can take place in the field, laboratory or at a decontamination facility in accordance with 5-21000-OPS-FO.03, *Field Decontamination Operations* or RMRS/OPS-PRO.070, *Equipment Decontamination at Decontamination Facilities*. Equipment decontamination is recorded in the facility logbook if the procedure is performed at the MDF or PADF. Water used for equipment decontamination will be treated at the CWTF.

5.4 PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment for sample collection is specified in the CWTF Health and Safety Plan. Disposable PPE generated during sampling shall be bagged and delivered to the Health and Safety Specialist for radiological screening (refer to 5-21000-OPS-FO.06, *Handling of Personal Protective Equipment* as appropriate).

5.5 RADIOLOGICAL SCREENING OF SAMPLES

The radiological screening of samples in preparation for off-site shipment will comply with 5-21000-OPS-FO.18, *Environmental Sample Radioactivity Content Screening.*

5.6 SAMPLE STORAGE, PACKAGING AND SHIPPING

When sampling is complete, the samples must be properly packaged and stored until they are shipped in accordance with RMRS/OPS-PRO.069, *Containing, Preserving, Handling, and Shipping Soil and Water Samples*, as applicable. The sampler/packer shall use best judgment when packing samples. Delivery of samples to the on-site lab will not require the stringent packaging requirements applicable to off-site shipments. If radiological screenings are required for off-site shipment, the samples should be securely stored until radiological screening results are received.

Non-radiological samples that are stored prior to shipment will be placed in the sample refrigerator to maintain a temperature of 4° C (2° C to 6° C). The samples are packaged in accordance with RMRS/OPS-PRO.069, *Containing, Preserving, Handling, and Shipping Soil and Water Samples* and shipped to the laboratory. The release of sample coolers for off-site shipment shall be in accordance with *Shipment of Radioactive Materials Samples* 4-B11-ER-OPS-FO.25, *Radioactive Material Transfer and Shipment*, 3-PRO-088-RSP-09.02 and *Unrestricted Release of Property, Material, Equipment and Waste*, 3-PRO-MI-RSP-09.01, as appropriate. Cooler temperatures will be checked upon arrival at the laboratory.

6.0 DATA MANAGEMENT

Each CWTF sample point is assigned a unique Soil and Water Database (SWD) location code and this unique code will be utilized on the COC form, applicable SWD forms and during input to and

retrieval from the SWD. The SWD location codes utilized at the CWTF are detailed in Table 4.1, Table 4.2, Table 4.3, Table 4.4 and Table 4.5.

Field observations samples (e.g., pH, conductivity, temperature, etc.) will be determined in the field and recorded on the Soil and Water Database Field Cap log sheet form. Field observations for sediment samples will include depth and collection method and will be recorded on the Soil and Water Database Field Cap log sheet form.

Chain of custody forms will be initiated for collected CWTF samples. The COC shall be maintained through sample storage and through all transfers of custody until the sample is received at the testing laboratory. COCs are archived for defensibility of the analytical and sampling data. Samples shall be logged in upon receipt at the analytical laboratory and the sample tracked throughout the analytical process in accordance with laboratory procedures. RMRS/OPS-PRO.069, *Containing, Preserving, Handling, and Shipping Soil and Water Samples* and 4-B29-ER-OPS-FO.14, *Field Data Management* will be followed during sampling activities.

Results from the radiological screen will be sent to the Responsible Manager. Other results will be submitted to the SWD to track, store and retrieve project data. The sample collection information submitted to the SWD will include sample number, volume collected or volume of container, sampler's name, sampling date, sample time and analyses in accordance with 4-B29-ER-OPS-FO.14, *Field Data Management.*

7.0 RECORDS

The following documents generated during the performance of this procedure must be controlled as follows:

Document	Record Type	Protection/Storage Methods	Processing Instructions
Chain of Custody Forms	QA	RM shall implement a reasonable level of protection to prevent loss and/or degradation while in process. Documents shall be protected utilizing standard office equipment and methods while in process.	Original is transferred to Analytical Services Division
SWD Logsheets	QA		RM transmits to RMRS Document Control

8.0 REFERENCES

1-10000-HWR, 1994, Hazardous Waste Requirements Manual

3-PRO-088-RSP-09.02, Radioactive Material Transfer and Shipment

3-PRO-MI-RSP-09.01, Unrestricted Release of Property, Material, Equipment and Waste

4-B11-ER-OPS-FO.25, Shipment of Radioactive Materials Samples

4-B29-ER-OPS-FO.14, Field Data Management

4-D99-WO-1100, Solid Radioactive Waste Packaging

4-I61-ENV-OPS-FO.43, Filter Press Operations and Cleaning – CWTF

5-21000-OPS-FO.03, Field Decontamination Operations

5-21000-OPS-FO.06, Handling of Personal Protective Equipment

5-21000-OPS-FO.18, Environmental Sample Radioactivity Content Screening

RF/ER-95-0118, CWTF Health and Safety Plan

RF/RMRS-98-200, Evaluation of Data for Useability in Final Reports

RMRS/OPS-PRO.069, Containing, Preserving, Handling and Shipping Soil and Water Samples

RMRS/OPS-PRO.070, Equipment Decontamination at Decontamination Facilities

RMRS/OPS-PRO.081, Surface Water Sampling

RMRS/OPS-PRO.144, CWTF Treated Effluent Discharge

RMRS/OPS-PRO.149, CWTF Influent Collection, Transfer and Storage Operations

RMRS/OPS-PRO.152, CWTF Treated Effluent Recirculation

RMRS/OPS-PRO.156, CWTF Ion Exchange System Neutralization and Transfer Operations

RMRS-QAPD-001, RMRS Quality Assurance Program Description

Building 891 Waste Stream Residue Identification Characterization, 1993. Rocky Flats Environmental Technology Site, Golden, Colorado.

Final Rocky Flats Cleanup Agreement, 1996. Rocky Flats Environmental Technology Site, Golden, Colorado.

Interim Measures/Interim Remedial Action Plan and Decision Document, 881 Hillside Operable Unit No. 1, 1990. Rocky Flats Environmental Technology Site, Golden, Colorado.

Rocky Flats Statement of Work for Analytical Measurements, 1997. Rocky Flats Environmental Technology Site, Golden, Colorado.

American Public Health Assn., 1995. Standard Methods for the Examination of Water and Wastewater.

ENVIROCARE, 1997. Customer Information Manual.

EPA SW-846, 1986. Test Methods for the Evaluation of Solid Waste: Physical/Chemical Methods.

EPA QA/G-4, 1994. Guidance for Using the Data Quality Objective Process.

Water Environment Federation, 1996. Methods for Chemical Analysis of Water and Wastes.

APPENDIX 1

CWTF Chemical Specific ARAR/Effluent Wastewater Treatment Standards[1]

Analyte	CAS Number	Action Level (ug/L)
Metals[a]		
Aluminum	7429-90-5	87
Antimony	7440-36-0	10*
Arsenic	7440-38-2	50
Barium	7440-39-3	1000
Beryllium	7440-41-7	5*
Cadmium	7440-43-9	5*
Chromium	7440-47-3	50
Copper	7440-50-8	16
Iron	7439-89-6	1000
Lead	7439-92-1	10*
Manganese	7439-96-5	1000
Mercury	7439-97-6	1
Nickel	7440-02-0	123
Selenium	7782-49-2	10*
Silver	7440-22-4	5*
Thallium	7440-28-0	12*
Zinc	7440-66-6	141
PCB's[b]		
Aroclor-1016	12674-11-2	1*
Aroclor-1221	11104-28-2	1*
Aroclor-1232	11141-16-5	1*
Aroclor-1242	53469-21-9	1*
Aroclor-1248	12672-29-6	1*
Aroclor-1254	11097-69-1	1*
Aroclor-1260	11096-82-5	1*
Semivolatile Organics[b]		
Acenaphthene	83-32-9	520
Acenaphthylene	208-96-8	10*
Anthracene	120-12-7	9600
Benzo(a)anthracene	56-55-3	10*
Benzo(a)pyrene	50-32-8	0.2*
Benzo(b)fluoranthene	205-99-2	10*
Benzo(g,h,i)perylene	191-24-2	10*
Benzo(k)fluoranthene	207-08-9	10*
bis(2-Chloroethyl)ether	111-44-4	10*
bis(2-Ethylhexyl)phthalate	117-81-7	10*
Butylbenzylphthalate	85-68-7	3000
4-Chloro-3-Methylphenol	59-50-7	50*
2-Chloronaphthalene	91-58-7	620
2-Chlorophenol	95-57-8	120
bis(2-Chloroisopropyl)ether	108-60-1	1400

Analyte	CAS Number	Action Level (ug/L)
Semivolatile Organics (cont.)		
Chrysene	218-01-9	10*
Dibenz(a,h)anthracene	53-70-3	10*
Di-n-butylphthalate	84-74-0	3650
1,2-Dichlorobenzene	95-50-1	620
1,3-Dichlorobenzene	541-73-1	400
1,4-Dichlorobenzene	106-46-7	75
3,3-Dichlorobenzidine	91-94-1	10*
2,4-Dichlorophenol	120-83-2	50*
Diethylphthalate	84-66-2	23000
2,4-Dimethylphenol	105-67-9	540
Dimethylphthalate	131-11-3	313000
4,6-Dinitro-2-methylphenol	534-52-1	50*
2,4-Dinitrophenol	51-28-5	50*
2,4-Dinitrotoluene	121-14-2	10*
2,6-Dinitrotoluene	606-20-2	230
Fluoroanthene	206-44-0	300
Fluorene	86-73-7	1300
Hexachlorobenzene	118-74-1	10*
Hexachlorobutadiene	67-68-3	10*
Hexachlorocyclopentadiene	77-47-4	10*
Hexachloroethane	67-72-1	
Indeno(1,2,3-cd)pyrene	193-39-5	
Isophorone	78-59-1	[illegible]
2-Methylphenol	95-48-7	1830
Naphthalene	91-20-3	620
Nitrobenzene	98-95-3	10*
n-Nitrosodiphenylamine	86-30-6	10*
n-Nitrosodipropylamine	621-21-7	10*
Pentachlorophenol	87-86-5	50*
Phenanthrene	85-01-8	10*
Phenol	108-95-2	2560
Pyrene	129-00-0	960
1,2,4-Trichlorobenzene	120-82-1	50
2,4,6-Trichlorophenol	88-06-2	50*
Volatile Organics		
Acetone	67-64-1	3650
Acrolein[b]	107-02-8	21
Acrylonitrile[b]	107-13-1	5*
Benzene	71-43-2	5
Bromodichloromethane	75-27-4	100
Bromoform	75-25-2	100
Bromomethane	74-83-9	48

[a] All metals are total
[b] Analyze only if detected in influent
* Practical quantitation limit (PQL)

APPENDIX 1

CWTF Chemical Specific ARAR/Effluent Wastewater Treatment Standards[1]

Analyte	CAS Number	Action Level (ug/L)
Volatile Organics (cont.)		
2-Butanone	78-93-3	21900
Carbon disulfide	75-15-10	3650
Carbon tetrachloride	56-23-5	5
Chlorobenzene	108-90-7	100
Chloroethane	75-00-3	29.4
Chloroform	67-66-3	100
Chloromethane	74-87-3	5.7
Dibromochloromethane	124-48-1	100
1,2 Dibromo-3-chloropropane[b]	96-12-8	1*
1,1-Dichloroethane	75-35-3	3650
1,1-Dichloroethene	75-35-4	7
1,2-Dichloroethane	107-06-2	5
1,2-Dichloroethene (trans)	156-60-5	100
1,2-Dichloropropane	78-87-5	1*
Ethylbenzene	100-41-4	680
Ethylene dibromide[b]	106-93-4	0.05
Methylene chloride	75-09-2	5
4-Methyl-2-pentanone	108-10-1	2920
Styrene	100-42-5	100
1,1,2,2-Tetrachloroethane	79-34-5	1*
Tetrachloroethene	127-18-4	5
Toluene	108-88-3	1000
1,1,1-Trichloroethane	71-55-6	200
1,1,2-Trichloroethane	79-00-5	1*
Trichloroethene	79-01-6	5
Vinyl chloride	75-01-4	2
Xylene (total)	1330-20-7	10000

Analyte	CAS Number	Action Level (mg/L)
Water Quality		
Cyanide (CN)[b]	57-12-5	0.005
Fluoride[b]	7782-41-4	2
Nitrate (as N) + Nitrite (as N)	14797-558-50	10
Sulfide (as H_2S)[b,d]	18496-258	0.002
pH		6.5 - 9.0

Analyte	CAS Number	Action Level (pCi/L)
Radionuclides[c]		
Americium-241	14596-10-2	0.15
Gross Alpha	14127-62-9	7
Gross Beta	12587-47-2	8
Plutonium 239 and 240	10-12-8	0.15
Strontium 90	11-10-9	8
Tritium	10028-17-8	500
Uranium	7440-61-1	11

[b] Analyze only if detected in influent
[c] Analyze as total radionuclides
[d] Limit is based on dissociated sulfide
* Practical quantitation limit (PQL)

[1]Based upon RFCA Agreement, Attachment 5, Table 1, Surface Water Action Levels & Standards, July 1996 and Draft Modifications to Attachment 5, Table 1, Surface Water Action Levels & Standards, March 1999.

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APPENDIX 1

CWTF Chemical Specific ARAR/Effluent Wastewater Treatment Standards Deviations to Surface Water Action Levels

ANALYTE	COMMENT
Metals	Using total instead of dissolved, total, and total recoverable. Cost saving measure and may be more stringent than the dissolved metals. Metals listed as dissolved and total recoverable will be analyzed as total.
Boron	No CRDL established, not under contract for analysis. Not expected to be present in influent.
Pesticides/Herbicides	Not expected to be present in influent
Aroclors	Analyzed only if detected in the influent. PQL of 2.0 ug/L will be used for action level for Ar-1221.
3,3-Dichlorobenzidine	Using PQL
Di(2-ethylhexyl)adipate, n-Nitrosodibutylamine, n-Nitrosodiethylamine, n-Nitrosodimethylamine, n-Nitrosopyrrolidine, Pentachlorobenzene, 1,2,4,5-Tetrachlorobenzene	Not on Target Compound List
1,2-Diphenylhydrazine	Degrades in analytical instrument injection port. Not on Target Compound List.
Acrylonitrile, Acrolein	Analyze only if detected in the influent. Using PQL.
bis(Chloromethyl)ether	Not listed in methods of analysis. Not under contract for analysis.
Dibromochloropropane 1,2-Dibromoethane	Analyze only if detected in the influent. Using PQL.
Cyanide	Using PQL
Sulfide	Analyzed only if detected in the influent.
Chromium, VI	Due to holding time requirements, total chromium will be analyzed. No historical influents containing hexavalent chromium.
Radium 226 and 228	No historical data for these.